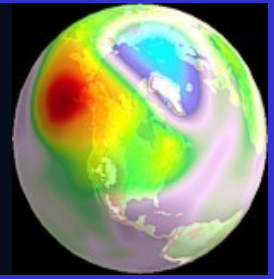




NRL Ozone Assimilation Mini-Workshop



Parameterized Ozone Photochemistry in the NOGAPS- ALPHA GCM

J. McCormack

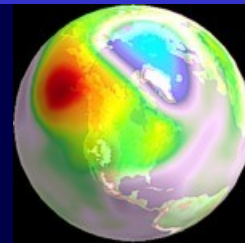
S. Eckermann, L. Coy, D. Allen

Naval Research Laboratory, Washington DC, USA



NOGAPS-ALPHA

NOGAPS with Advanced Level Physics-High Altitude



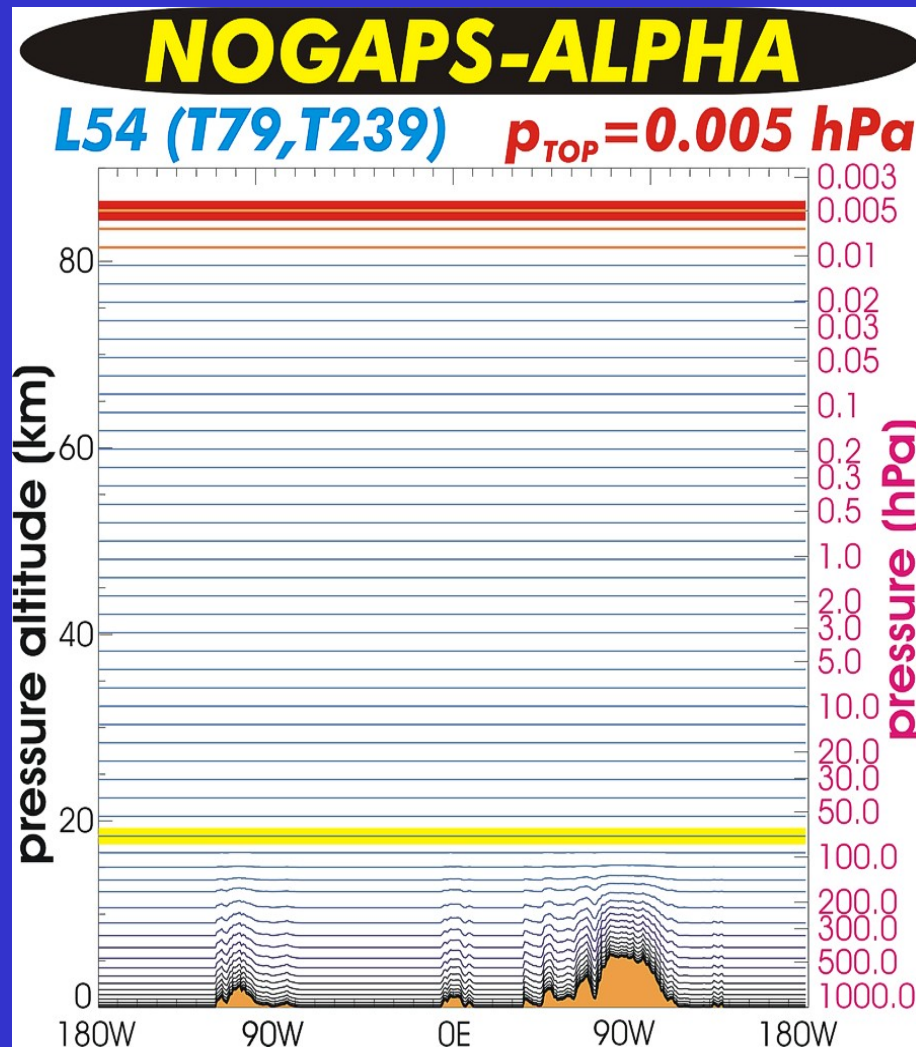
Motivations for Prognostic Ozone in NOGAPS-ALPHA

- Improved satellite radiance assimilation
- Prognostic ozone feeds into model radiative heating calcs
→ Improved forecasts

Model Configuration

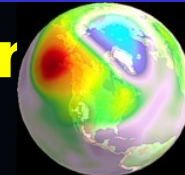
- Model top at 0.005 hPa (z~85 km)
- T79 & T239 spectral truncation
- CLIRAD radiation scheme currently uses 2D O₃
- New 3D prognostic ozone features

- spectral transport





Linearized O₃ Photochemistry Scheme for NOGAPS-ALPHA



If we assume a Taylor series expansion about a mean state (f_o, T_o, c_o) after *Cariolle and Déqué* [1986] (“CD86”) and *McLinden et al* [2000] (“LINOZ”).

$$\frac{df}{dt} = (P-L)^o + \left. \frac{\partial(P-L)}{\partial f} \right|_o (f - f^o) + \left. \frac{\partial(P-L)}{\partial T} \right|_o (T - T^o) + \left. \frac{\partial(P-L)}{\partial c_{O_3}} \right|_o (c - c^o_{O_3})$$

1

2

3

4

NOGAPS Fields

1. Ozone Mixing Ratio, f
2. Temperature, T
3. Column O₃, c

Photochemistry Parameters (y, z, t Lookup Tables)

1. Mean/Equilibrium Production-Loss $(P-L)_o$
2. Photochemical Relaxation Timescale $\tau = -[d(P-L)/df]_o^{-1}$
3. Temperature Perturbation Coefficient $[d(P-L)/dT]_o$

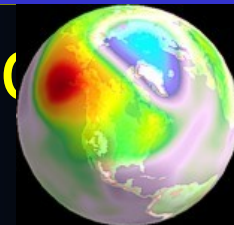
Climatological Fields

1. Ozone $f_o(y, z, t)$
2. Temperature $T_o(y, z, t)$
3. Column O₃

NOGAPS-ALPHA prognostic O₃ can use photochemistry parameters of either **CD86 (ECMWF), **LINOZ**, **NRL CHEM2D**, or Goddard (NCEP) → inter-comparison of the 4 different photochemistry schemes**



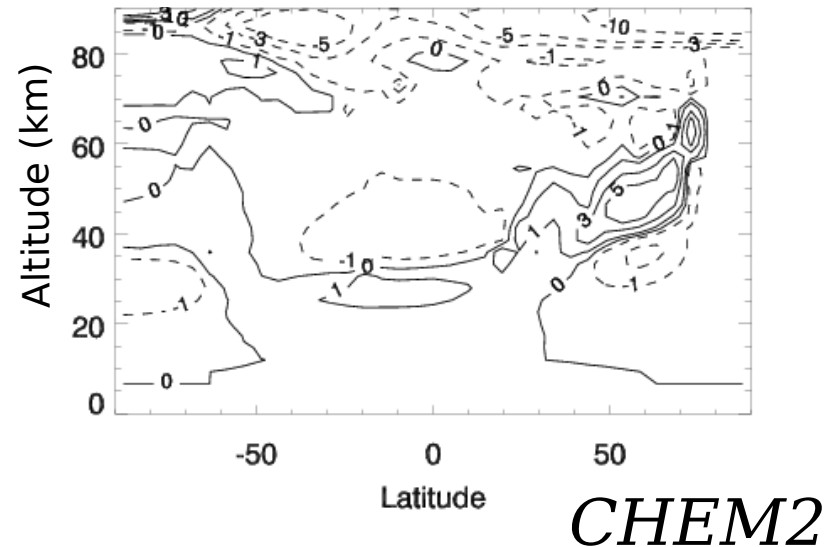
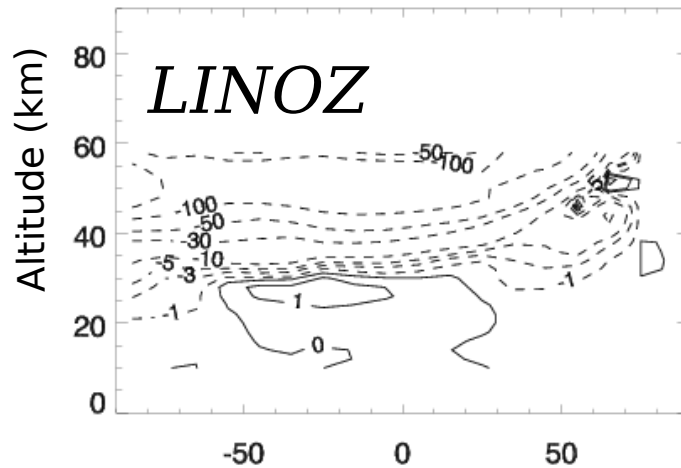
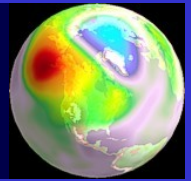
3 photochemistry schemes tested in NOGAPS-ALPHA



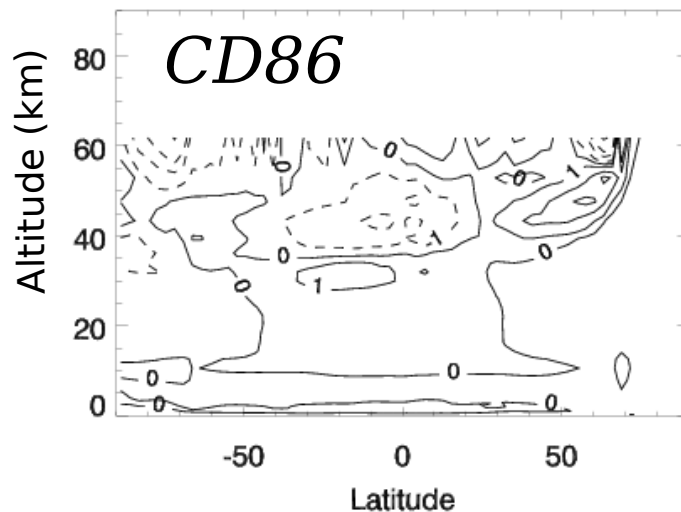
	1. $P-L$ (ppmv/s)	2. $\frac{d(P-L)}{df}$ (s^{-1})	3. $\frac{d(P-L)}{dT}$ (ppmv/K)	4. $\frac{d(P-L)}{dc_{O_3}}$ (ppmv/DU)	5. PSC effects
CD86 ($z_{top} \sim 61$ km)	yes	yes	yes	yes	yes (Cl loading)
LINOZ ($z_{top} \sim 58$ km)	yes	yes	yes	yes	no
CHEM2D V0 ($z_{top} \sim 85$ km)	yes	yes	preliminary (v1.0)	future work?	testing "cold tracer"
GSFC/NCEP	no	yes	no	no	no



Term 1: O_3 (P-L) in ppmv/month



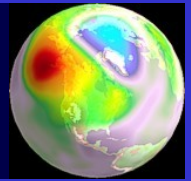
D



LINOZ O_3 (P-L) above 10 hPa yields *large* low ozone bias

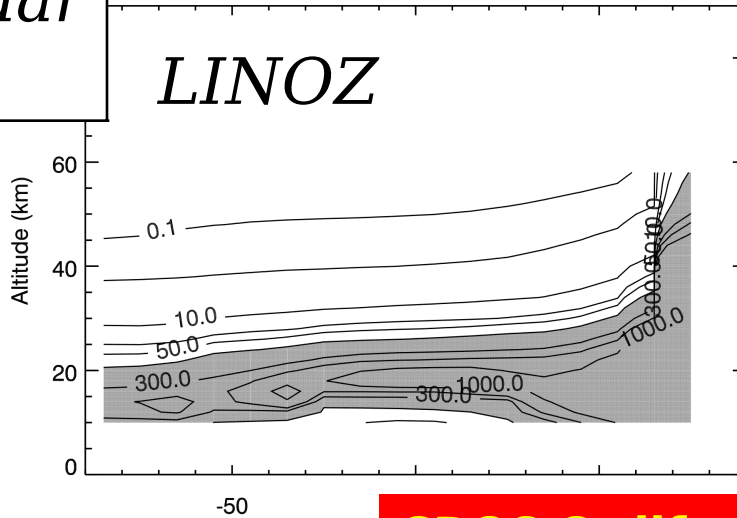


Term 2: O₃ Relaxation Time (Days)

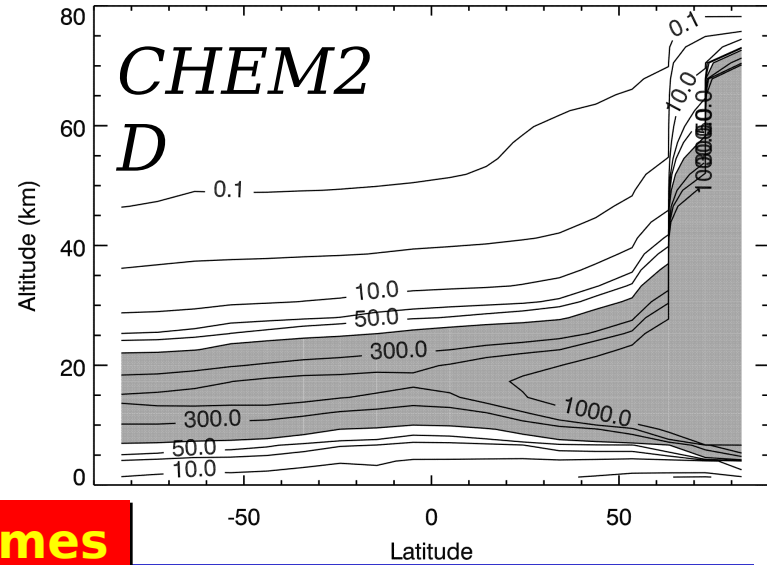


January

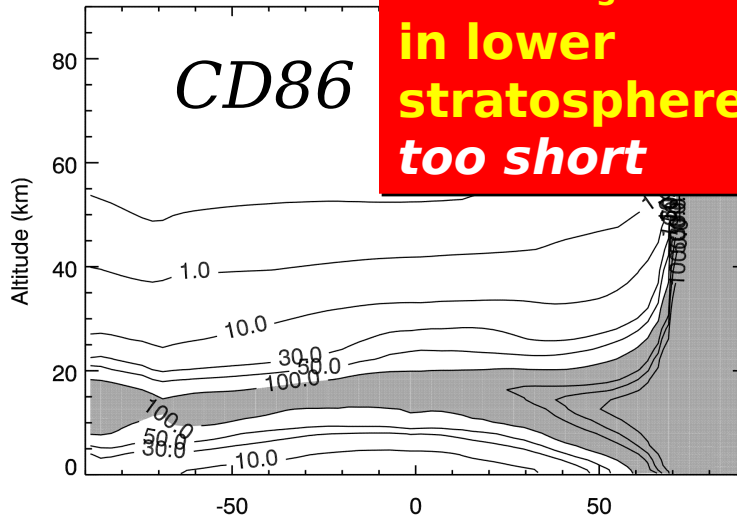
LINOZ



*CHEM2
D*

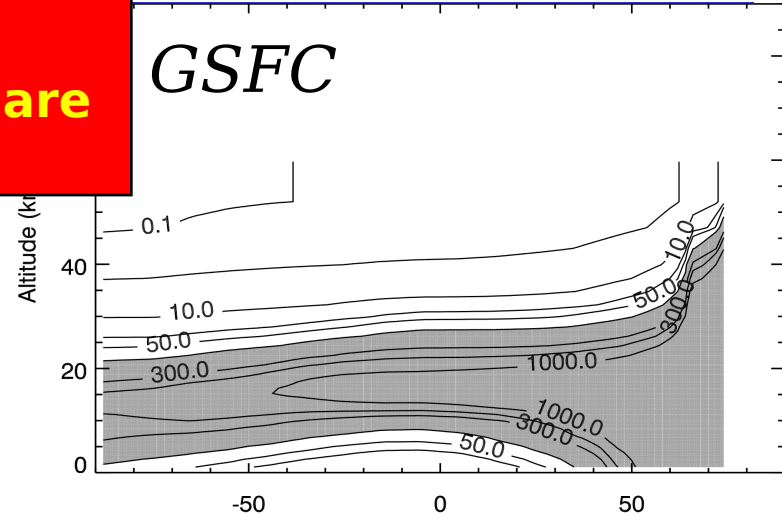


CD86



**CD86 O₃ lifetimes
in lower
stratosphere are
too short**

GSFC





SAGE III Ozone Loss and Validation Experiment (SOLVE 2 Jan - Feb 2003)



BRITISH ATMOSPHERIC
DATA CENTRE



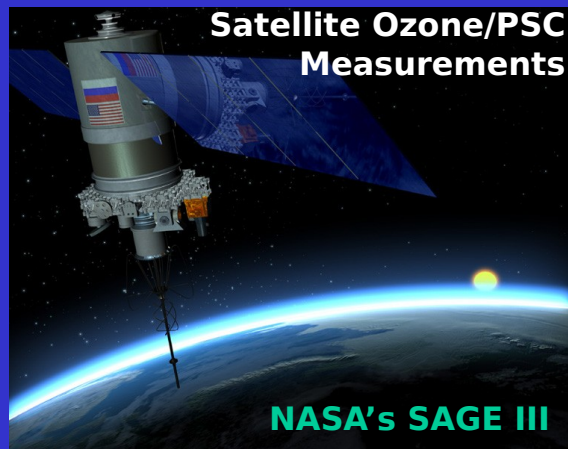
European Centre
for Medium-Range
Weather Forecasts



NAVAL RESEARCH
LABORATORY

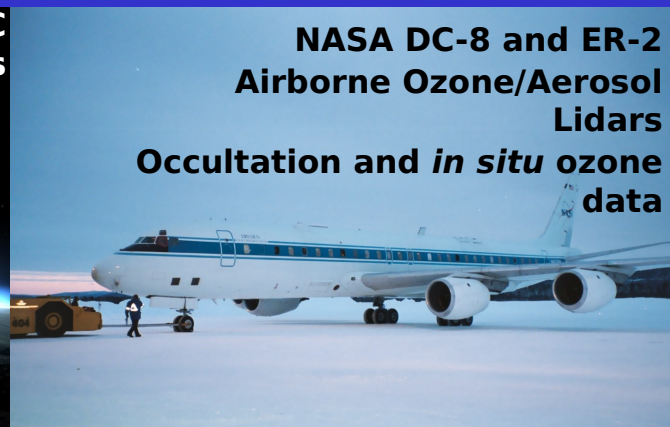


Naval Research Laboratory
MWFM
Mountain Wave Forecast Model



Satellite Ozone/PSC
Measurements

NASA's SAGE III



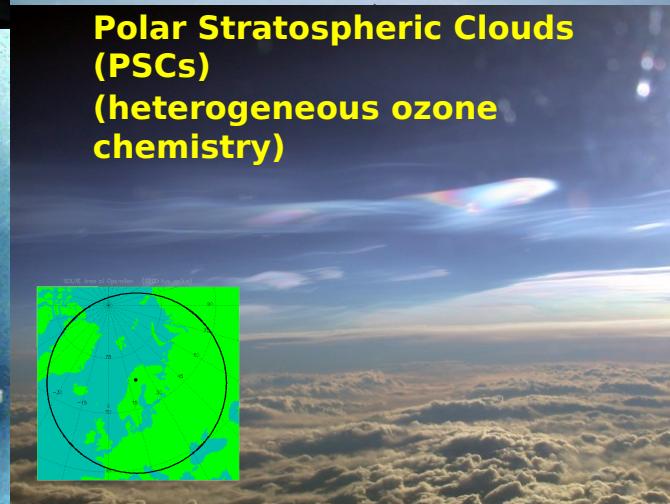
NASA DC-8 and ER-2
Airborne Ozone/Aerosol
Lidars
Occultation and *in situ* ozone
data



High-Altitude Balloons



NRL's POAM III



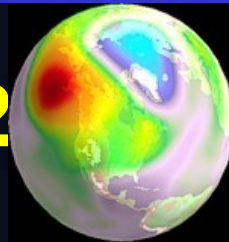
Polar Stratospheric Clouds
(PSCs)
(heterogeneous ozone
chemistry)



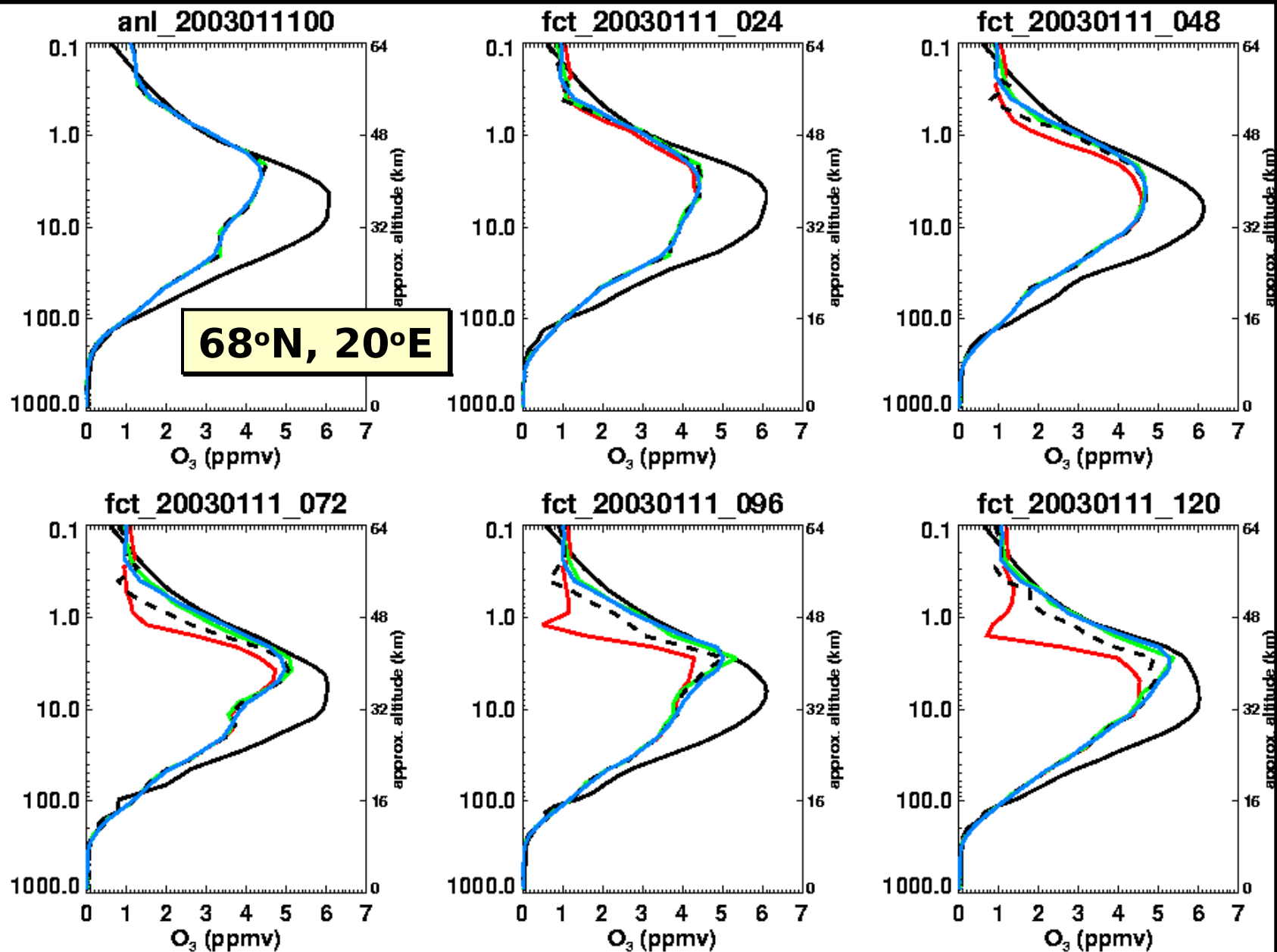
Ozone and PSCs
from Ground-Based
Lidar



NOGAPS Hindcasts: SOLVE2



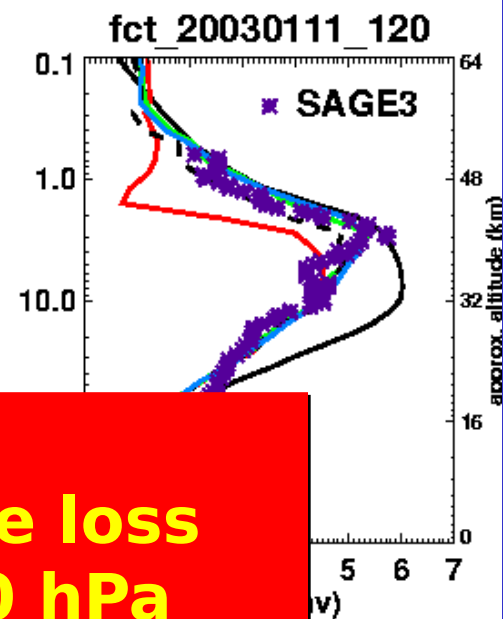
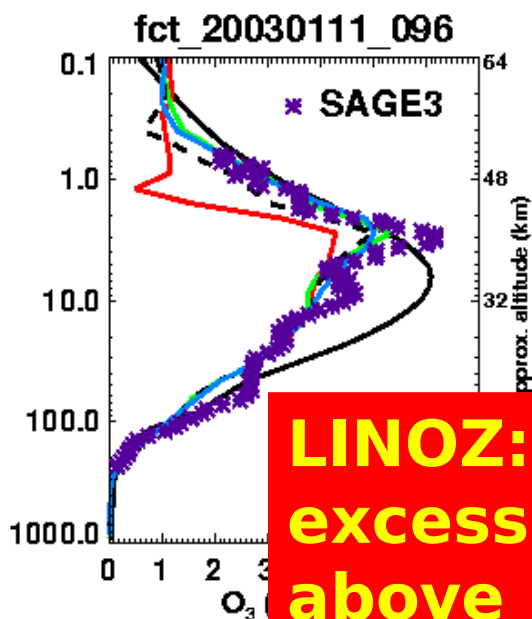
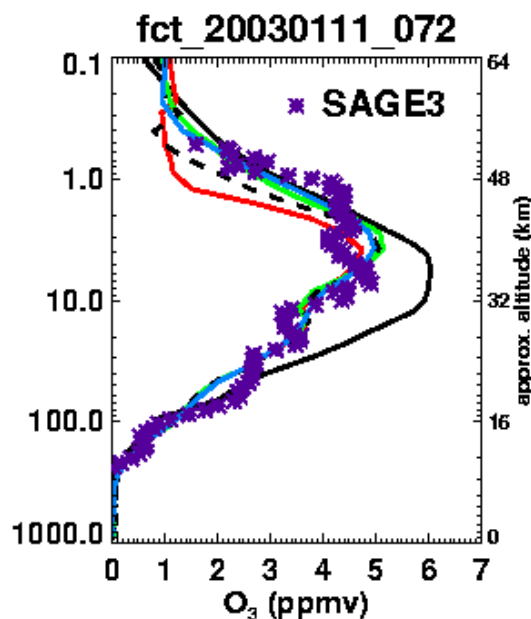
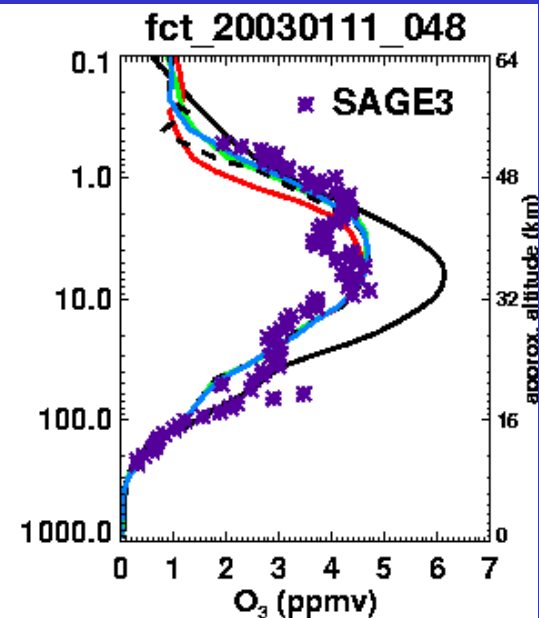
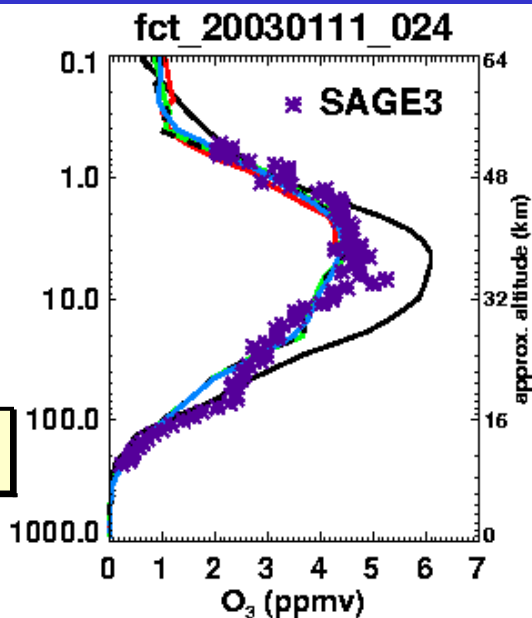
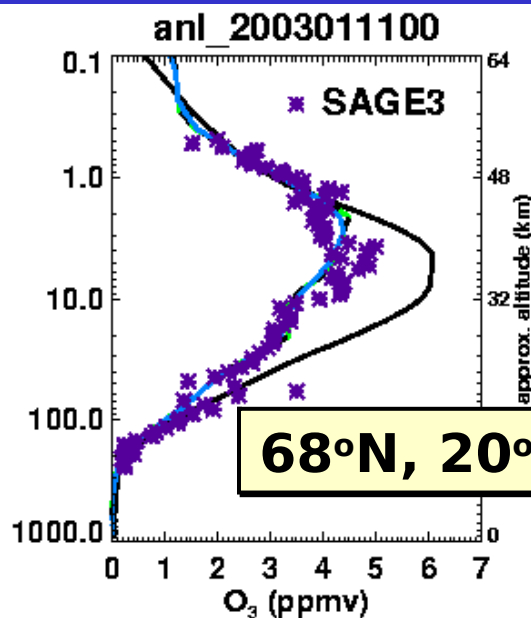
- **SOLVE2 provided our first opportunity to test new NOGAPS-ALPHA 3-D O₃ initialization, transport & photochemistry.**
- **We compared results from 5-day hindcasts of interesting ozone events in Jan 2003 using CD86, LINOZ, and CHEM2D V0, initialized with GMAO or ECMWF IFS 3D assimilated ozone fields**
- **Overall the best results were obtained with the CHEM2D V0 scheme, despite the fact it has no temperature or column ozone terms**
- **For more details see [McCormack et al., Atmos. Chem. Phys., 4, 2401-2423, 2004.](#)**



ECMWF **NGP-passive (dashed)**
NGP-LINOZ

NGP-CHEM2D

NGP-CD86



**LINOZ:
excessive loss
above 10 hPa**

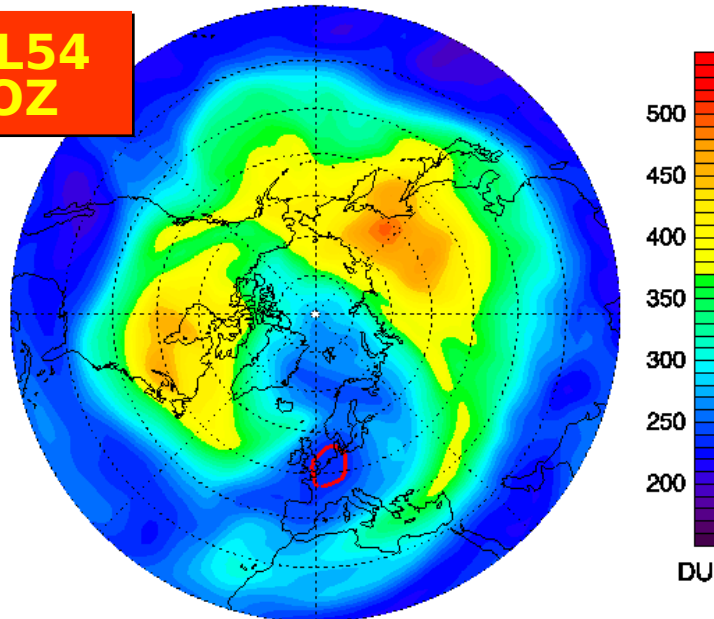
ECMWF NGP-passive (dashed)
NGP-LINOZ

NGP-CHEM2D

NGP-CD86

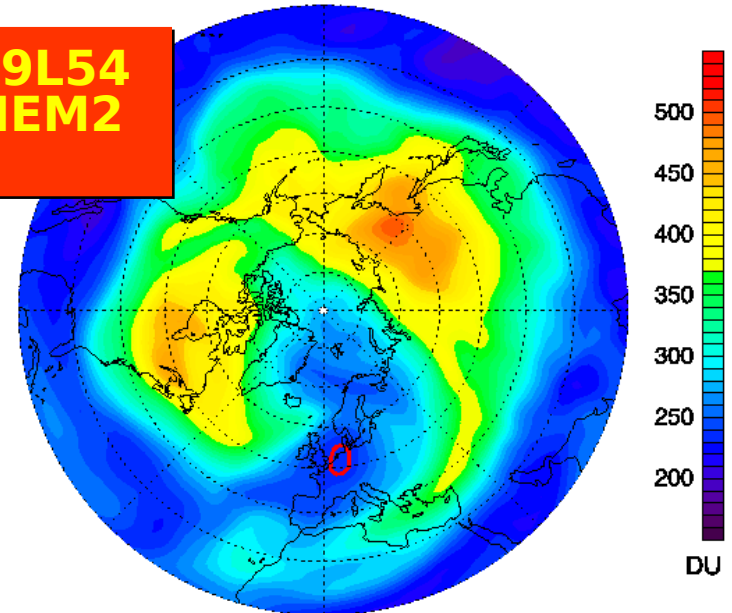
NOGAPS- α FCT TOTOZ : 2003011100 : t = 000096 h

**T79L54
LINOZ**



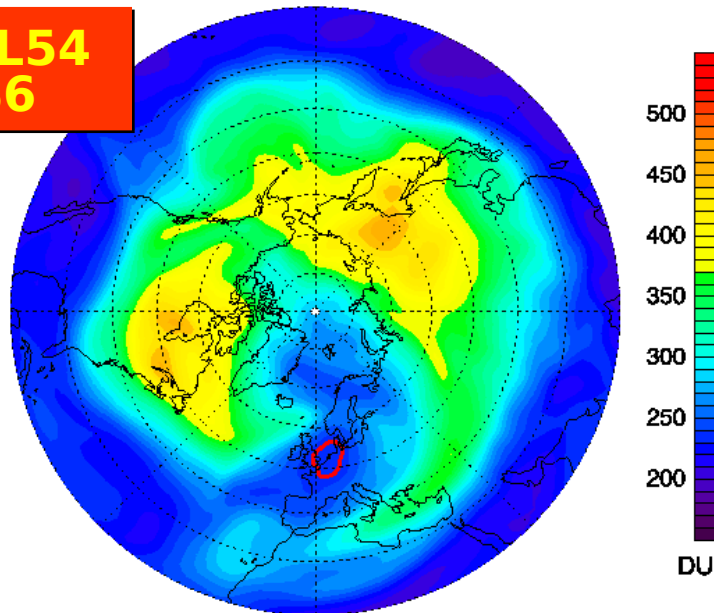
NOGAPS- α FCT TOTOZ : 2003011100 : t = 000096 h

**T79L54
CHEM2
D**



NOGAPS- α FCT TOTOZ : 2003011100 : t = 000096 h

**T79L54
CD86**

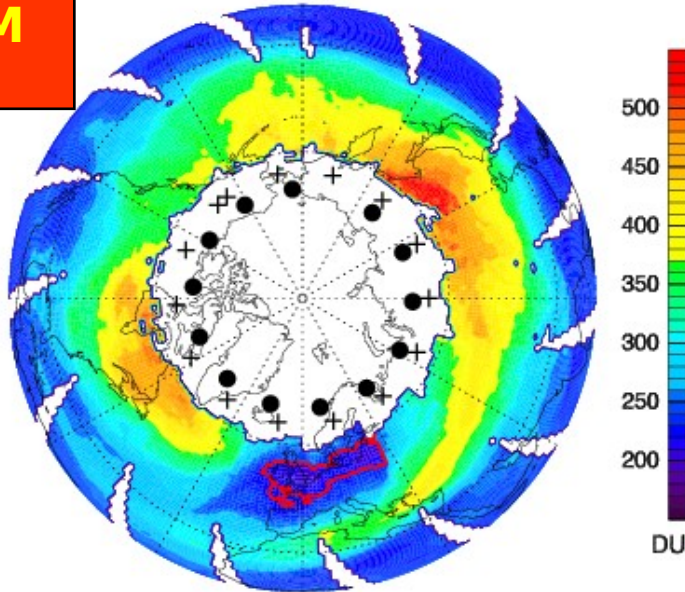


***TOTAL OZONE : 15
Jan 0Z***

photochemistry schemes
yield similar results for
total ozone. In the lower
stratosphere, the very
short **CD86** O₃ relaxation
time ($\tau = -[d(P-L)/df]_0^{-1}$)
smooths out zonal structure

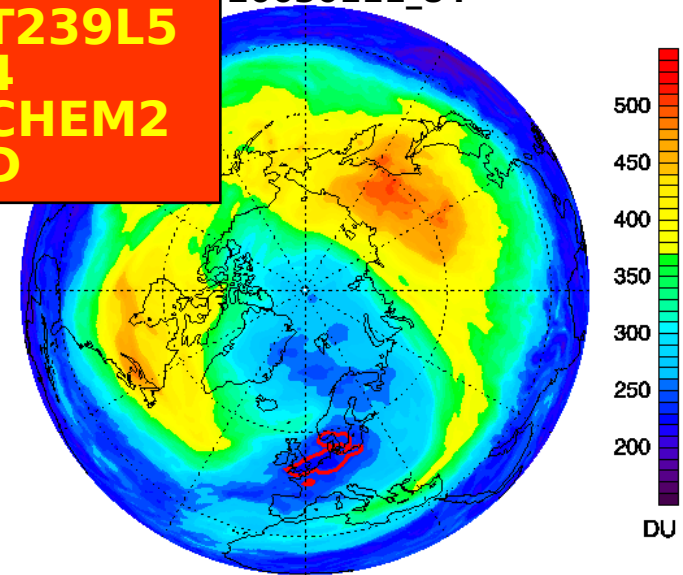
**EPTOM
S**

EPTOMS : 20030114



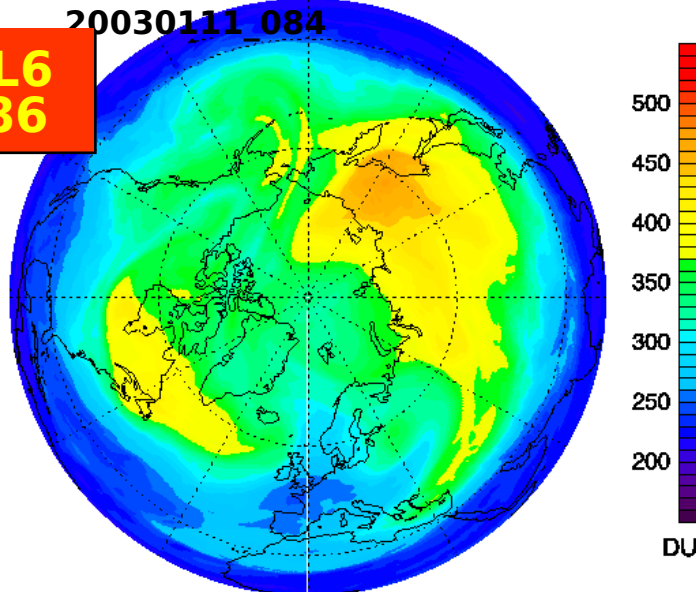
**NOGAPS-ALPHA :
20030111_84**

**T239L5
4
CHEM2
D**



**OPERATIONAL ECMWF:
20030111_084**

**T511L6
0 CD86**



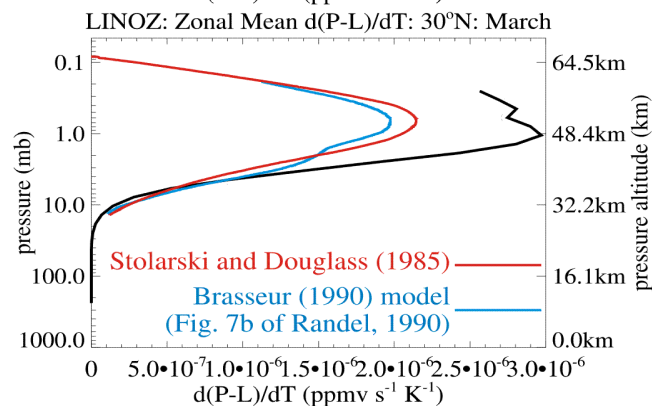
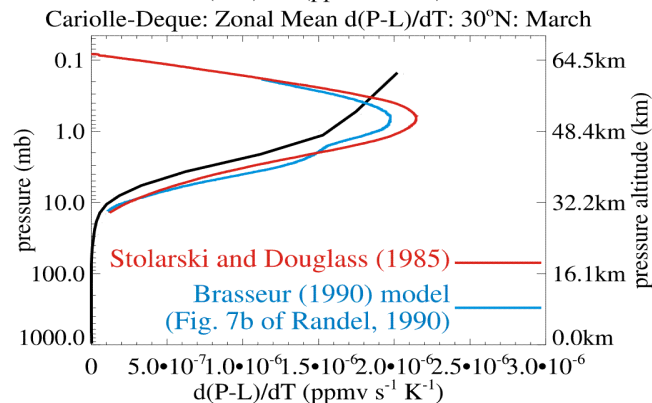
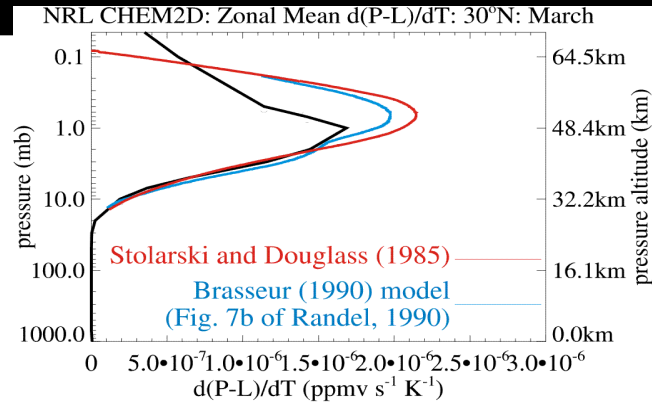
- NASA EPTOMS observes an ozone “mini-hole” feature over Western Europe on 14 Jan 2003
- Operational ECMWF T511L60 ozone forecasts issued on 11 Jan under-predicts the mini-hole.
- NOGAPS-ALPHA T239L54 hindcast initialized 11 Jan with GMAO O₃ and using V0 CHEM2D scheme captures mini-hole feature.

Including temperature dependence in CHEM2D scheme: "V1.0"

CHEM2D V1.0

CD86

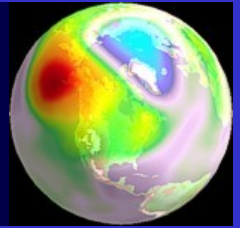
LINOZ



**$d(P-L)/dT$
for March
30° N**



Summary



	1. $P-L$	2. $\frac{d(P-L)}{df}$	3. $\frac{d(P-L)}{dT}$	4. $\frac{d(P-L)}{dc_{O_3}}$
CD86 ($z_{top} \sim 61$ km)	ok	X (τ too short)	ok	ok
LINOZ ($z_{top} \sim 58$ km)	X (too much loss above 10 hPa)	ok	X (too large above 1 hPa)	ok
CHEM2D V0 ($z_{top} \sim 85$ km)	ok	ok	✓ preliminary (v1.0)	?
GSFC/NCEP ($z_{top} \sim 60$ km)	-	ok	-	-14